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Avoiding Armageddon: Long-term Asteroid Orbit Deflection Optimization with Kinetic Impactors

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The National Aeronautics and Space Administration (NASA), USA

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Given sufficient warning time current technology would, in principle, allow humankind to avert potentially disastrous collisions between asteroids and our planet. So-called “kinetic impactor” spacecraft (KI) could transfer momentum to sub-kilometer-sized, potentially hazardous asteroids through high-velocity collisions in order to increase the encounter distance with the Earth. Crater ejecta resulting from such a kinetic impact are believed to contribute significantly to the total momentum transferred to an asteroid. The “free” additional momentum, the as well as the relative simplicity of the approach make this deflection technique very economical. The momentum added by crater ejecta is largely uncertain in magnitude and direction. It can, therefore, not be counted on in the planning of a deflection attempt. Moreover, uncertainties in the delivered momentum weaken predictions of the post-impact orbit. Without accurate information on where an asteroid is “parked” after a deflection attempt, it is difficult to guarantee that the same object does not become a concern for planetary safety once again in the future. In the worst case, the target asteroid enters a secondary gravitational keyhole. Such unfortunate circumstances would render a deflection attempt moot, as the asteroid retains a high probability to collide with our planet at a later date. Many of those downsides are a consequence of the fact that a single KI deflection constitutes and open-loop control mechanism. One possible avenue to tackle the aforementioned challenges is to improve the control. How to optimally target an asteroid during a kinetic deflection maneuver so as to exclude Earth impacts in the foreseeable future despite all state and process uncertainties is elaborated in my presentation. An application to the Double Asteroid Redirection Test (DART) mission concept will also be discussed. Another way of mitigating uncertainties in KI-based asteroid deflection is closing the control loop. This can be achieved by sending multiple kinetic impactor spacecraft, thus, turning the deflection campaign into a discrete-in-time optimal control problem under uncertainty. As this research is still under development, I intend to give an overview of its current state and discuss aspects that could benefit from local expertise.

Dr. Siegfried Eggl is a Caltech postdoctoral scholar at the NASA Jet Propulsion Laboratory working on asteroid orbit deflection mission concepts such as the Double Asteroid Redirection Test (DART). Dr. Eggl started his career as a lecturer and graduate researcher at the University of Vienna, Austria. After completing his PhD in Astrophysics in 2013, Dr. Eggl moved to Paris, France. At the Institut de Mécanique Céleste et de Calcul des Ephémérides (IMCCE) he co-developed the current European planetary defense strategy and designed manifold based trajectories as a contractor for Airbus Defense and Space. In 2016, Dr. Eggl accepted an appointment at JPL with the Solar System Dynamics group to continue his research on asteroid orbit deflection. Apart from his involvement in planetary defense, Siegfried advises a student at JPL working on the trajectory design for NASA’s “Psyche” mission. He also runs a successful astrophysics research program that connects celestial mechanics with climatology to better understand the prerequisites for planetary habitability in multiple star systems. His publications in highly regarded journals such as “Nature” and “The Astrophysical Journal” have been cited several hundred times.

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